DOE Business Plan for the Office of Science's Princeton Plasma Physics Laboratory

Mission and Overview

The Princeton Plasma Physics Laboratory (PPPL) is the only Department of Energy Lab devoted primarily to plasma and fusion science and is the leading U.S. institution investigating the physics of magnetic fusion energy. Magnetic fusion research at Princeton began in 1951 under the code name Project Matterhorn. Now PPPL is host to the Collaborative National Center for plasma and fusion science. Plasma is hot ionized gas in which nuclear fusion occurs under the appropriate conditions of temperature, density, and confinement in a magnetic field. PPPL's mission focus is to make the scientific discoveries and develop the key innovations that will lead to an attractive new energy source; conduct world-class research along the broad frontier of plasma science and technology; and provide the highest quality of scientific education. For three decades PPPL has been a leader in magnetic confinement experiments using the tokomak approach. To deepen the understanding of plasmas and create key innovations to make fusion power a practical reality, PPPL is leading work on an advanced fusion device, the National Spherical Torus Experiment, and developing other innovative confinement concepts. The lab hosts other experimental facilities used by multi-institutional research teams and also sends researchers and specialized equipment to other fusion facilities in the U.S. and abroad.

Lab-at-a-Glance

Location: Princeton, NJ

Type: Single-program lab

Contract Operator: Princeton University

Responsible Field Office: Princeton Site Office

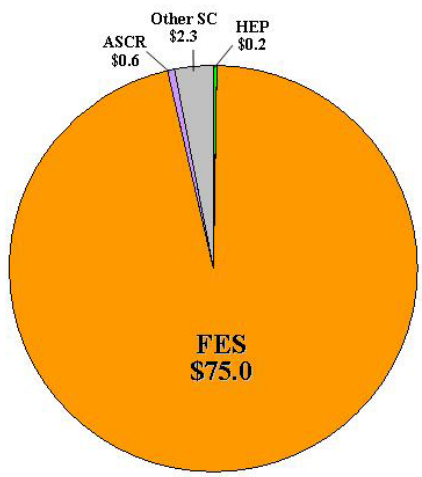
Website: http://www.pppl.gov/

Physical Assets:
- 36 buildings
- 88 acres

Human Capital:
- 408 employees (9/05)
- 35 graduate students
- 119 Facility Users and Visiting Scientists

FY 2005 Total DOE Funding: $78.1M

FY 2005 DOE Funding by Source
PALS data (BA in Millions):



FY 2005 Non-DOE Funding: $1.5M

Laboratory Focus and Vision

Three core competencies underpin business line activities at the Princeton Plasma Physics Laboratory:

1. Experimental plasma physics in the areas of: construction and operation of unique fusion facilities; diagnostic development and application; radio-frequency plasma heating and experimental research in all facets of physics of magnetized plasmas.
2. Theoretical plasma physics in the areas of: computational turbulence studies; nonlinear MHD studies; understanding fast-ion induced instabilities; and providing national theory coordination for the Spherical Torus and Stellarator initiatives.
3. Computation in the areas of: algorithm development; massive parallelization; portability; visualization; and shared fusion code library.

The Office of Science believes that these three competencies will enable PPPL to deliver its mission focus, to perform a complementary role in the DOE laboratory system, and to pursue its vision for scientific excellence and pre-eminence in the areas of:

- Research, experimentation, simulation, engineering and design in burning plasmas;
- Research and experimentation to increase fusion power at given size and field;
- Investigations to achieve compact efficient steady-state operations; and
- Fundamental understanding of plasma behavior, including instabilities, sufficient to provide predictive capabilities for design of fusion energy systems.

Business Lines

The following capabilities, aligned by business lines, distinguish PPPL and provide a basis for effective teaming and partnering with other DOE laboratories, universities, and private sector partners in pursuit of the laboratory mission. These business lines and the distinguishing capabilities outlined in the table below provide an additional window into the mission focus and unique contributions and strengths of PPPL and its role within the Office of Science laboratory complex. Items in italics within the column, Distinguishing Capabilities, identify research facilities that convey particular, strategic strengths and capabilities to the Lab. Descriptions of these facilities can be found at the website noted in the Lab-at-a-Glance section of this Plan.

Business Lines	Distinguishing Capabilities	Distinguishing Performance	Mission Relevance
Burning Plasma Physics	• **Experimental research in all facets of physics of magnetized plasmas;** • **Constructed and operated the only D-T experiment in the U.S;** • **Leaders in developing diagnostics, radio frequency and current drive heating system;** • **Engineers who designed and operated fusion experiment with tritium as a fuel;** • **Engineers and designers with expertise in electromagnetic, structural, thermal and neutronics codes;** • *National Spherical Torus Experiment.*	Leading experimental and theoretical/ computational research in all facets of physics of magnetized plasmas; Leaders in developing diagnostics, radio frequency and current drive heating systems; Engineers who designed and operated fusion experiment with deuterium-tritium as a fuel; Engineers and designers with expertise in electromagnetic, structural, thermal and neutronics codes.	Demonstrate with burning plasmas the scientific and technological feasibility of fusion energy.
Increased Fusion Power at Given Size and Field	• **Experimental research in all facets of physics of magnetized plasmas;** • **World leading spherical torus experiment;** • **Most powerful heating systems;** • **High beta (ratio of plasma pressure to magnetic field pressure);** • **Unique world leading diagnostic tools;** • *ITER participation.*	Leading experimental and theoretical/computational research in all facets of physics of magnetized plasmas; World-leading high beta results (ratio of plasma pressure to magnetic field pressure).	Determine the most promising approaches and configurations to confining hot plasmas for practical fusion energy systems.
Compact Efficient	• **Experimental research in all facets**	Leading experimental and	Determine the most promising

Business Lines	Distinguishing Capabilities	Distinguishing Performance	Mission Relevance
Steady-State Operation	**of physics of magnetized plasmas;** • **Optimized for continuous operations with little recirculating power;** • *National Compact Stellarator Experiment.*	theoretical/computational research in all facets of physics of magnetized plasmas; Successful design of world-leading compact configuration for efficient continuous operation.	approaches and configurations to confining hot plasmas for practical fusion energy systems.
Theoretical and Computational Understanding	• **Computational turbulence studies;** • **Computational macro-stability studies;** • **Understanding fast ion induced instabilities and macrostability;** • **Algorithm development;** • **Massive parallelization;** • **Visualization.**	Leading computation in: plasma turbulence; plasma macro-stability; and fast ion induced instabilities studies; Parallelization and visualization development.	Develop a fundamental understanding of plasma behavior sufficient to provide a reliable predictive capability for fusion energy systems.

Major Activities

Following is a set of major activities that PPPL would like to pursue to support aspects of the DOE mission and build on core strengths and capabilities of the laboratory. The Office of Science is examining all of these potential activities and they are at different stages of development. Some are currently underway and some are mere concepts at this time. For those that are still in the conceptual phase, PPPL has indicated significant interest and is viewed to have current supporting research and mission focus to pursue such activities. Budgets, the Office of Science's strong commitment to a fair and competitive funding process and technical advice from its major scientific advisory committees will ultimately contribute to decisions about which activities can be pursued and at which sites. The companion documents, the DOE's Five Year Plans, provide greater insights into these activities in terms of various five-year budget scenarios.

The major activities are:

1. ITER
2. National Spherical Torus Experiment (NSTX)
3. National Compact Stellarator Experiment (NCSX)
4. Collaborative Computing

1. ITER

- **Summary:** An international collaboration based around a fusion tokamak experiment operating at over 100 million °C and producing 500 MW of fusion power for over 400 seconds. ITER will be located in Cadarache, France. Oak Ridge National Lab (ORNL) in partnership with PPPL will host the U.S. ITER Project Office.
- **Expectations:** To provide key knowledge to build the first electricity-generating fusion power station based on magnetic confinement of high temperature plasma - in other words, to capture and use the power of the sun on Earth.
- **Benefit Perspective:** Potentially *Transformational* Benefits - a new non-carbon energy source.
- **Risk Perspectives:**

- Technical: *High risk* - will be pushing many state-of-the-art technologies to their limits.
- Market/Competition: *Low risk* - provided the U.S. participates in the experiment and gains for the U.S. knowledge needed to build fusion power plants in the future.
- Management/Financial: *High risk* - due to the collaboration of multiple countries with different approaches to project management, and the magnitude of funding required.

ITER will be an unprecedented international collaboration of seven partners involved in fusion research worldwide. PPPL will support the U.S. members of the ITER Council to address key risk issues including: risk-based management approaches that lead to cost-effective construction; and a research program structure that fosters integrated international teams, providing the U.S. with wide opportunities regardless of the levels of financial contribution.

An experienced PPPL/ORNL leadership team has been assembled to mitigate the technical ITER risks, which arise from pushing multiple state-of-the-art technologies to their limits, and provide for the successful design, construction and operation of ITER. Members of the broader U.S. Fusion Team will be invited to participate on various tasks assigned to the ITER team. This U.S. team will work with the international ITER team to establish effective management techniques including the application of value engineering.

2. NSTX

- **Summary:** Study the physics principles of spherically shaped plasmas using The National Spherical Torus Experiment (NSTX). Results from this innovative magnetic fusion device will provide unique scientific input to the ITER Project.
- **Expectations:** NSTX will continue to lead the world in developing fusion systems with very high beta (ratio of plasma pressure to magnetic field pressure), allowing cost-effective magnets to contain powerful fusion plasma. NSTX will address issues of fusion science, including energetic particle physics, inaccessible in any other device worldwide. Research on NSTX will also address compact, efficient continuous operation.
- **Benefit Perspective:** Potentially *Transformational* Benefits
- **Risk Perspectives:**
  - Technical: *Moderate risk* due to the complexity of the devices and the potential for coil failure. Risk is mitigated by having long lead items available to build new components if necessary.
  - Market/Competition: *Low risk* due to a strong lead in the world. Other facilities cannot match its heating, diagnostic, and control capabilities.
  - Management/Financial: *Low risk* due to proven financial and management systems and current operation.

NSTX produces plasma that is shaped like a sphere with a hole through its center, different from the "donut" shaped plasmas of conventional tokamaks. This innovative plasma configuration may have several advantages, a major one being the ability to confine a higher plasma pressure for a given magnetic field strength (allowing it to provide unique scientific input for ITER). This has been demonstrated both experimentally and theoretically. Since the amount of fusion power produced is proportional to the square of the plasma pressure, the use of spherically shaped plasmas could allow the development of smaller, more economical fusion reactors, as well as a cost effective Component Test Facility.

3. NCSX

- **Summary:** A new experimental facility, the National Compact Stellarator Experiment (NCSX), is under construction as the centerpiece of the U.S. effort to develop the physics and determine the attractiveness of the compact stellarator as the basis for a fusion power reactor.

- **Expectations:** NCSX will help lead the world in developing fusion systems that operate continuously with very little power required to sustain the plasma configuration. Research on NCSX will also address the attainment of high beta and thus efficient use of the magnetic field. NCSX will assist researchers in developing the best configuration for holding hot plasma in the magnetic fields.
- **Benefit Perspective:** Potentially *Transformational* Benefits
- **Risk Perspectives:**
  - Technical: *Moderate risk* due to the complexity of the devices and cutting edge technologies. Risks are mitigated with intentional redundancies in research and production of complex elements.
  - Market/Competition: *Low risk* due to a lack of comparable research elsewhere.
  - Management/Financial: *Moderate risk* due to the complexity of the configuration.

The NCSX will be built at the Princeton Plasma Physics Laboratory in partnership with Oak Ridge National Laboratory. The NCSX is now in design and construction. First plasma is scheduled for 2009. NCSX will lead the world in developing fusion systems that operate continuously with very little power required to sustain plasma configuration.

4. Collaborative Computing

- **Summary:** Maximize potential from ongoing experiments, while assisting in daily research and development of innovations, through collaborations among the U.S. fusion science community in the development of computer codes and sharing computational resources.
- **Expectations:** Collaborative Computing will minimize the technical risks of fusion research throughout the U.S.
- **Benefit Perspective:** Potentially S*ubstantial* Benefits
- **Risk Perspectives:**
  - Technical: *Low risk* due to prior prototype.
  - Market/Competition: *Low risk* due to a lack of similar research elsewhere.
  - Management/Financial: *Low risk* due to relatively small cost and prior experience.

Advanced computing has already been proven useful in optimizing the design of devices used in fusion research, such as NCSX, and the communication of research data among the fusion research community is a practical and necessary aspect of achieving the overall goal of affordable fusion energy. The Computational Plasma Physics Group (CPPG) currently plays a key role in this Fusion Collaboratory. As an example, PPPL's TRANSP code is currently being used worldwide for data interpretation via the Fusion GRID. PPPL has had great success maintaining this large code on a single architecture and making it available through the GRID.

Financial Outlook

Detailed information regarding the financial outlook for the Princeton Plasma Physics Laboratory is subject to 1) competition and merit review, 2) the availability of appropriated funds and 3) programmatic decisions. The first two factors can not be predicted or estimated in advance. The third, programmatic decisions, are developed in accordance with the planning targets reflected in the Department of Energy programmatic Five Year Plans, a companion document to these strategic laboratory business plans. In addition, because of the Office of Science commitment to competition and merit review, there is often a time lag between programmatic decisions and the determination of which research provider can best deliver the greatest value in conducting the research. Thus, it is not always apparent how programmatic decisions unfold for particular laboratories. Nevertheless, some decisions, such as the plans for large scientific user facilities, show clear paths to individual labs and therefore inform their business plans.

Uncertainties and Risk Management

External Factors: Over the next five years, PPPL will have concerns driven by external forces. Primary among these is the budget outlook for the Laboratory. Other concerns include; the Princeton University prime contract expires in 2006; implementation of Homeland Security Presidential Directive-12 (HSPD-12) and foreign visits and assignments; and meeting the DOE 2% Maintenance Investment Index Goal in FY06.

S&T Workforce: PPPL has faced challenges associated with reductions in laboratory staffing. PPPL recently offered a voluntary separation program in which 29 individuals participated. Staffing scenarios are presented in the historical staffing graph below.

Diversity: Diversity continues to be an important goal at PPPL, however, the decline in staff levels has challenged implementation. As with most DOE labs, PPPL must make significant progress in the recruitment and retention of under-represented populations. Critical to the success of this commitment is realization of constrained ideal funding projections as well as success of a diverse workforce development pipeline.

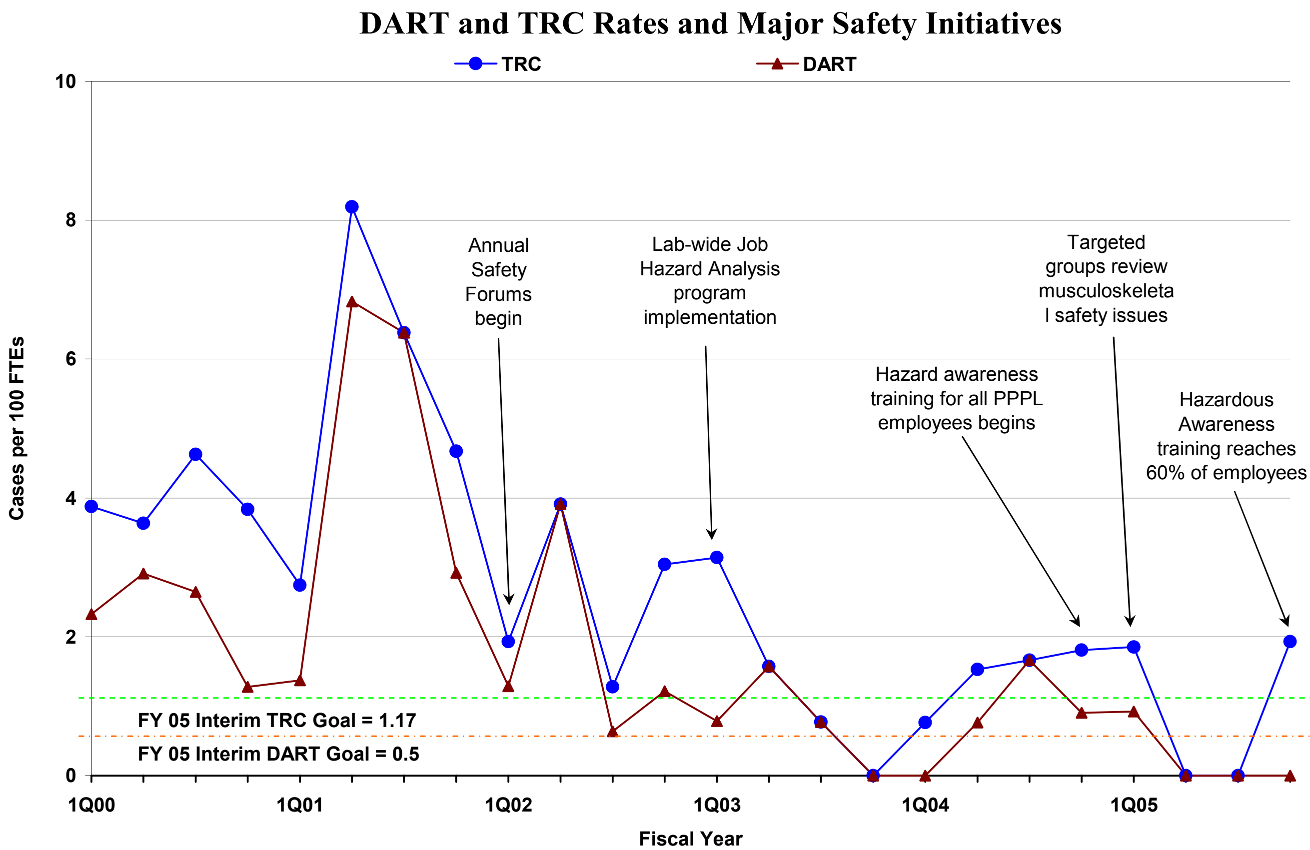
PPPL will continue a number of educational outreach activities to ensure long-range goals in increasing the availability of women and minorities in science and technology by developing and enhancing feeder programs initiatives including:

- Educational and Research Experiences—via the National Undergraduate Fellowship Program and the Student Undergraduate Laboratory Internship Program;
- K-12 Science Education Program—learning opportunities at PPPL encouraging women and underrepresented minorities to explore science as a career;
- Target recruiting of minority and women candidates; and
- Continue to achieve diversity representation in postdoctoral research, focusing on increasing the numbers of women and minorities (based on funding and the ability to hire post docs).

In FY05, PPPL implemented a Staff Search Report requirement before an offer of employment can be extended. The hiring manager, employment manager and deputy director must sign off and agree that an earnest effort was made to diversify the pool of candidates and fill the position with a qualified woman or minority. The goal of this review is to assure that diversity at PPPL is improved. This level of commitment from the Director's Office has sent a clear message about the seriousness and business relevance of the issue of diversity. There is a stated expectation of cooperation and has resulted in more involvement and commitment from senior management and their staffs. PPPL also conducts an annual review of minority and women promotions and salary. No inequities have been found to date, however, if they are identified in the future, PPPL will correct the problem and ensure equity.

The focused activities on recruiting, developing, promoting and retaining will have long-term impacts on ensuring a diverse workplace which recognizes and rewards all staff.

Safety: Safety continues to be a top priority at PPPL. During FY05, PPPL has had four TRC cases and one DART case. PPPL is currently better than the Office of Science average in both of these statistics. The number of incidents at the laboratory has steadily decreased for the past 4 years, and a number of preventive activities are being initiated including: Hazard Awareness Training; small group musculoskeletal safety; small group discussions on electrical safety following the SLAC Arc Flash Incident; emphasis on safety in annual employee performance evaluations; Annual Safety Forum; and the Director has participated in the Management Safety Walkthrough Program. PPPL is planning to apply for the review and certification of the DOE Voluntary Protection Program as Princeton University continues to participate in laboratory safety reviews and the Laboratory's Executive Safety Board.



Physical Infrastructure: PPPL is located on 89 acres of Princeton University land near Princeton University outside Princeton, NJ. Established as a Federal laboratory in the 1960s, PPPL has over 724,000 sf of space in 35 buildings; 35% of the space as well as many of the utility systems and roads, are 40 years old, or older. PPPL's AUI is 0.978 (good).

Maintenance, recapitalization, and modernization are supported with overhead, operating, and GPP funds, and with line item funding. PPPL will attain a maintenance investment level of 1.9% of replacement plant value (excellent) in FY 2006 which will be continued in FY 2007 and the outyears. PPPL's deferred maintenance backlog is $11.5M resulting in an ACI of 0.92 (adequate). A deferred maintenance reduction initiative was initiated in FY 2006 and will continue in FY 2007 with funding of $.396M. The FY 2007 GPP funding request is for $1.8M.

Improvements are being made over the next three years to some existing buildings to prepare them for the National Compact Stellerator Experiment, at the same time that some older buildings are being demolished in order to consolidate staff and reduce costs. PPPL's future modernization challenge is to renovate nine 40 year old buildings to extend their life and increase their versatility and flexibility for upcoming mission work.